

[0045] As described above, when a metal layer made of any one material of tantalum, nickel, palladium, and molybdenum (MO) is formed on the aluminum layer 10, the aluminum layer 10 reacts with the metal layer at the time of annealing and a compound layer of the material that forms the metal layer and aluminum is generated at the interface between the aluminum layer 10 and the metal layer as a result. In this case, the semiconductor device comprises the compound layer of the material that forms the metal layer and aluminum between the aluminum layer 10 and the metal layer.

[0046] The reason that the source electrode 12 and the drain electrode 13 as an ohmic electrode are configured as described above in the present embodiment is as follows.

[0047] First, tantalum (Ta) has a melting point as extremely high as about 3,000° C. and is excellent in thermal stability, and the work function thereof is smaller than that of titanium (Ti). In addition, a compound generated when tantalum (Ta) and aluminum (Al) react with each other has a melting point higher than that of a compound generated when titanium (Ti) and aluminum (Al) react with each other. Therefore, tantalum (Ta) is used instead of titanium (Ti) conventionally used. Due to this, it is possible to improve the thermal stability and mechanical strength of the ohmic electrodes 12 and 13 considerably. In particular, it is possible to realize the ohmic electrodes 12 and 13 excellent in the long-term reliability in a high temperature environment.

[0048] Materials having a high melting point include tungsten, however, it is rather difficult to continuously evaporate tungsten for formation using, for example, the electron beam-physical vapor deposition (EB-PVD), therefore, tantalum (Ta) is used taking into consideration the easiness in handling during process.

[0049] Further, the reason that a Ta/Al stacked structure is employed is in order to suppress electromigration of the Al atom during operation at high temperatures by forming the tantalum layer 9 having a high melting point below the aluminum layer 10.

[0050] If the aluminum layer 10 is formed on the tantalum layer 9, the tantalum layer 9 and the aluminum layer 10 react with each other at the time of annealing and a compound layer of them is generated as a result at the interface between the tantalum layer 9 and the aluminum layer 10. In this case, the semiconductor device comprises, as a result, the compound layer of tantalum and aluminum between the tantalum layer 9 and the aluminum layer 10.

[0051] On the other hand, if aluminum (Al) is exposed on the electrode surface, there is a possibility that the electrode surface may be corroded in a high humidity environment. Therefore, on the Ta/Al stacked structure, a metal layer (cap layer) made of any one material of tantalum (Ta), palladium (Pd), nickel (Ni), and molybdenum (Mo) as a metal material having moisture resistance, that is, a metal material resistant to, for example, water, ammonium, hydrochloric acid, etc., is stacked to cover the surface of aluminum (Al), and thus the surface of the ohmic electrodes 12 and 13 is suppressed from being corroded.

[0052] As described above, the margin of the process is extended by forming the metal layer using a metal material, the melting point of the metal alone of which is high, the melting point of which is still high even after turning into a compound by reacting with aluminum (Al), and which has moisture resistance, on the Ta/Al stacked structure.

[0053] In particular, in a case where the source electrode 12 and the drain electrode 13 as an ohmic electrode are configured so as to have a Ta/Al/Ta stacked structure, a structure is constructed in which the aluminum (Al) layer 10 is sandwiched in the vertical direction by the tantalum (Ta) layers 9 having the same coefficient of thermal expansion, therefore, when annealing is performed, for example, at temperatures below 600° C. (preferably, in the range of 530° C. to 570° C., or most preferably, 550° C.) in order to obtain the ohmic properties, the thermal stresses of the upper and lower tantalum (Ta) layers 9 are cancelled and an effect can be obtained that hillocks are prevented from occurring in the aluminum (Al) layer 10 by thermal cycle.

[0054] Due to this, as shown in FIG. 4(A) and FIG. 4(B), it is possible to suppress the electrode surface from becoming coarse and a flat and excellent surface can be obtained (that is, a surface hillock suppression effect is obtained) In other words, it will be understood that by employing the Ta/Al/Ta stacked structure, the electrode surface is suppressed from becoming coarser than the electrode surface [refer to FIG. 8(A) and FIG. 8(B)] in the Ta/Al stacked structure proposed in the course of development of the present invention, as shown in FIG. 4(A) and FIG. 4(B), and a flat and excellent surface can be obtained.

[0055] Materials having a high melting point include tungsten, however, it is rather difficult to continuously evaporate tungsten for formation using, for example, the electron beam-physical vapor deposition (EB-PVD), therefore, anyone of tantalum (Ta), palladium (Pd), nickel (Ni), and molybdenum (Mo) is used taking into consideration the easiness in handling during process.

[0056] Next, the method for manufacturing a semiconductor device (for example, GaNFET) according to the present embodiment is described with reference to FIG. 3(A) to FIG. 3(J).

[0057] First, as shown in FIG. 3(A), the intentionally undoped GaN electron transit layer 2 (for example, 3 μm in thickness), the electron supply layer 3 made of an n-type $\text{Al}_{0.25}\text{Ga}_{0.75}\text{N}$ layer (n-AlGa_{0.75}N layer; for example, 20 nm in thickness; Si doping concentration of $2 \times 10^{18} \text{ cm}^{-3}$), and the n-GaN layer 8 [for example, 10 nm or less in thickness (for example, 5 nm); Si doping concentration of $2 \times 10^{18} \text{ cm}^{-3}$] are stacked in order on the SiC (silicon carbide) substrate 11 to form a stacked structure using the normal metal organic chemical vapor deposition (MOVPE) method.

[0058] A spacer layer [intentionally undoped $\text{Al}_{0.25}\text{Ga}_{0.75}\text{N}$ layer (i-AlGa_{0.75}N layer; for example, 3 nm in thickness)] may be provided between the electron transit layer 2 and the electron supply layer 3. Further, the configuration of the n-GaN layer 8 is not limited to this and it is only necessary to use one doped with n-type impurity materials of $1 \times 10^{17} \text{ cm}^{-3}$ or more.

[0059] Next, as shown in FIG. 3(A), separation between elements is performed by, for example, applying a resist 15 and performing ion implantation to make both sides inactive. Separation between elements may be performed by removing both sides by etching.

[0060] Next, as shown in FIG. 3(B) to FIG. 3(E), on the n-AlGa_{0.75}N electron supply layer 3, the source electrode 12 and the drain electrode 13 as an ohmic electrode are formed using the deposition lift-off method.

[0061] In other words, first, as shown in FIG. 3(B), after resists (here, two layers) 15A and 15B are applied to the entire surface, patterning is performed so that an opening is